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(54) **High strength cold rolled steel sheet having excellent non-aging property at room temperature and suitable for drawing and method of producing the same.**

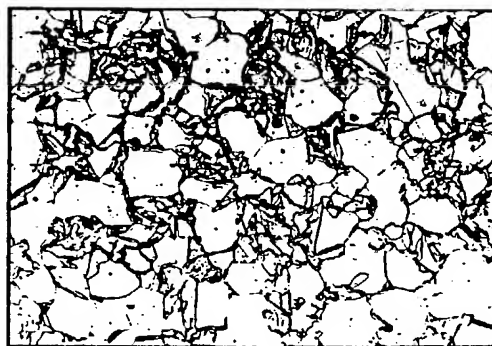
(57) The invention in its first aspect provides a high strength cold rolled steel sheet having excellent non-aging property at room temperature and excellent drawability, said steel sheet having a dual-phase structure composed of a high-temperature transformed ferrite phase and a low-temperature transformed ferrite phase having high dislocation density, said steel sheet having a composition which essentially contains: not less than 0.001 wt% but not more than 0.025 wt% of C, not more than 1.0 wt% of Si, not less than 0.1 wt% but not more than 2.0 wt% of Mn, not less than 0.001 wt% but not more than 0.2 wt% of Nb, not less than 0.0003 wt% but not more than 0.01 wt% of B, not less than 0.005 wt% but not more than 0.10 wt% of Al, not more than 0.1 wt% of P, not more than 0.007 wt% of N, at least one selected from a group consisting of not less than 0.05 wt% but not more than 3.0 wt% of Ni, not less than 0.01 wt% but not more than 2.0 wt% of Mo and not less than 0.05 wt% but not more than 5.0 wt% of Cu, and the balance being substantially Fe with inevitable impurities. This steel sheet is produced by preparing a hot-rolled steel sheet having the above-specified composition, cold rolling the hot-rolled steel sheet at a rolling reduction not smaller than 60 %, annealing the cold rolled steel sheet at a temperature which is not lower than the  $\gamma$  transformation start temperatures but below the  $A_{c3}$  transformation temperature, and cooling the annealed steel sheet at a rate not smaller than 5°C/sec but not greater than 100°C/sec.

The invention in its second aspect provides a high strength cold rolled steel sheet having excellent non-aging property at room temperature and bake hardenability, as well as excellent drawability, said steel sheet exhibiting a tensile strength not smaller than 45 Kgf/mm<sup>2</sup> and having a dual-phase structure composed of a high-temperature transformed ferrite phase and a low-temperature transformed ferrite phase having high dislocation density, said steel sheet having a composition which essentially contains: more than 0.008 wt% but not more

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than 0.025 wt% of C, not more than 1.0 wt% of Si, not less than 0.1 wt% but not more than 2.0 wt% of Mn, not more than 0.2 wt% but not less than five times the content of C of Nb, not less than 0.0003 wt% but not more than 0.01 wt% of B, not less than 0.005 wt% but not more than 0.10 wt% of Al, not more than 0.1 wt% of P, not more than 0.007 wt% of N, and the balance being substantially Fe with inevitable impurities. This steel sheet is produced by preparing a hot-rolled steel sheet having the above-specified composition, cold rolling the hot-rolled steel sheet at a rolling reduction not smaller than 60 %, annealing the cold rolled steel sheet at a temperature which is not lower than the  $\gamma$  transformation start temperature but below the  $A_{c3}$  transformation temperature, and cooling the annealed steel sheet at a rate not smaller than 5 °C/sec but not greater than 100 °C/sec.

FIG. 4



( $\times 400$ )

## BACKGROUND OF THE INVENTION

## Field of the Invention

5 The present invention relates to a high strength cold rolled steel sheet which has a high tensile strength of 40 Kgf/mm<sup>2</sup> or higher and excellent non-aging property at room temperature and which is suitable for uses where specifically high press formability is required, e.g., automotive panels and the like, as well as in the production of hot-dip galvanized steel sheet which is now facing an increasing demand, and also to a method for producing such a steel sheet.

10 The present invention also is concerned with a high strength cold rolled steel sheet which has a high tensile strength of 45 Kgf/mm<sup>2</sup> or higher and excellent non-aging property at room temperature, as well as high bake hardenability (BH property) and which can suitably be used in the fields mentioned above, and also to a method of producing such a steel sheet.

In recent years, cold rolled steel sheets for drawing are required to meet the following requirements:

- 15 (1) greater strength to reduce both weight and cost while improving safety  
 (2) improved applicability to production of hot-dip galvanized steel sheet which is light-weight and superior in corrosion resistance

Various methods have been conventionally used for strengthening cold rolled steel sheet for working, typical examples of which are solid solution strengthening by addition of P and Mn, strengthening by formation of dual-phase structure of martensite and so forth, and precipitation strengthening caused by precipitation of Cu or like elements.

Application of steel sheets strengthened by solid-solution strengthening to drawing, however, is practically limited because such strengthening method causes a deterioration in workability. Further, addition of P which is the most effective element for strengthening the steel with minimum deterioration of workability conspicuously impedes zinc plating characteristic.

25 The strengthening by formation of the conventionally known dual-phase structure essentially requires addition of a comparatively large quantity of C, e.g., 0.05 to 1.0 wt%, in order to enable appearance of martensite and bainite as the second phase. Consequently, the steel sheet having the conventionally known dual-phase structure is not suitable for drawing, because the Lankford value (the r-value) conspicuously drops. In addition, martensite and bainite are undesirably annealed during galvannealing, which not only results in reduction of strength but allows generation of stretcher strain during forming. For these reasons, the steel sheets strengthened by the conventionally known dual-phase structure is not suitable for hot-dip galvannealing.

Precipitation strengthening tends to restrict conditions of production of steel sheets due to necessity for optimization of precipitation processing. In particular, production efficiency is seriously impaired when a precipitation treatment is additionally employed in the production process.

It has also been known that steel sheets can be hardened by aging caused by accumulation of solid-solution C to dislocation which occurs during baked-on-finish, i.e., hardened by bake hardenability of the steel. In a strict sense, bake-hardening is different from precipitation-strengthening. The bake-hardened steel sheets, however, are widely used because the bake-hardening can be effected without substantially burdening the production process. Bake-hardening, however, provides only a small increase in the tensile strength, e.g., 1 to 2 Kgf/mm<sup>2</sup> or so, although it improves tensile rigidity due to increase of yield strength by 3 to 5 Kgf/mm<sup>2</sup>. In addition, means are necessary for preventing aging before working or during plating. Thus, bake-hardening method also has disadvantages.

45 Consequently, known strengthening methods for strengthening steel sheets having high drawability have practical limits and steel sheets strengthened by such methods are not suitable for use as the material of hot-dip galvanized steel sheets.

Under these circumstances, one of the present inventors, together with four other inventors, has proposed, in Japanese Patent Laid-Open No. 60-174852, a new type of cold rolled steel sheet and a method of producing the same, more specifically, a cold rolled steel sheet possessing excellent deep drawability and having a dual-phase structure composed of a ferrite phase and a low temperature transformed ferrite phase produced by annealing of extremely low carbon steel sheet in the temperature region where  $\alpha$  and  $\gamma$  phases coexist, as well as a process for producing such cold rolled steel sheet.

In contrast to known dual-phase-structure steel sheet having martensite and bainite as the second phase, the steel sheet proposed in Japanese Patent Laid-Open No. 60-174852 has the second phase constituted by low-temperature transformed ferrite having a high dislocation density.

The form of the low-temperature transformed ferrite varies according to the steel composition. According to an optical microscopic observation, the low-temperature transformed ferrite has one or a combination

of two or more of the following three forms:

- (1) crystal-like form with irregularly keened grain boundaries
- (2) crystal grain-like form existing along grain boundaries in the same manner as precipitates
- (3) crystal grain-like state or a state of a group of crystal grains (many sub-grain boundaries are found in comparatively large second phase grain) having a scratch-like form

The low-temperature transformed ferrite, therefore, can be clearly distinguished from ordinary ferrite. In addition, the low-temperature transformed ferrite also can be clearly distinguished from martensite and bainite because the corroded portion inside the grain exhibits a color tone which is similar to that of ordinary ferrite and which is different from those of martensite and bainite.

On the other hand, an electron-microscopic observation reveals that the low-temperature transformed ferrite has a very high dislocation density in grain boundaries and/or grains. In particular, the low-temperature transformed ferrite in the third form (3) mentioned above exhibits a laminated structure having portions of extremely high dislocation density, and comparatively low dislocation density.

In the steel sheet having the dual-phase structure composed of ferrite phase and low-temperature transformed ferrite phase as the second phase, the second phase is not annealed even when the steel is subjected to a high temperature of 550 °C, unlike the known cold rolled steel sheets having a second phase constituted by martensite or bainite which are easily annealed. The steel having the above-mentioned dual-phase structure, therefore, is suitable for use as the material of hot-dip galvanized steel sheets.

The steel sheet having the above-mentioned dual-phase structure also is superior in that the r-value is much higher than those of steel sheets having conventional dual-phase structure, due to the fact that the matrix phase is constituted by extremely-low carbon ferrite which has been recrystallized at ordinary high temperature. In addition, this steel sheet simultaneously exhibits both high bake hardenability and non-aging property at room temperature, because the dual-phase structure has internal local strain.

The strengthening effect produced by low-temperature transformed ferrite is not so remarkable as compared with the effect produced by martensite or bainite. In order to further strengthen the steel sheet, therefore, it is necessary to add strengthening elements such as Mn, Nb and B. Addition of such elements to the steel of the kind described, however, tends to deteriorate workability and extremely restricts the range of annealing temperature which would provide good workability, with the result that the production efficiency is lowered.

## SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to eliminate problems such as impairment of workability and production efficiency encountered with the strengthening of steel sheet having a dual-phase structure composed of high-temperature transformed ferrite phase and low-temperature transformed phase which has high dislocation density, thereby to provide a high strength cold rolled steel sheet which has excellent deep drawability and excellent non-aging property at room temperature and which is suitable for use as the material of hot-dip galvanized steel sheet, as well as a method of producing such a high strength cold rolled steel sheet.

Another object of the present invention is to provide a high strength cold rolled steel sheet which exhibits excellent bake hardenability in addition to the foregoing advantageous features, as well as a method of producing such a high strength cold rolled steel sheet.

The present invention in its first aspect provides a cold rolled steel sheet having the following physical target values:

Tensile strength (TS)  $\geq 40$  Kgf/mm<sup>2</sup>  
 TS x EI (Elongation)  $\geq 1800$  Kgf/mm<sup>2</sup>·%  
 r-value (mean)  $\geq 1.8$

yield point elongation immediately after annealing, hot-dip galvannealing or skin-pass rolling or after 6-month aging after such treatment

< 0.5 %.

The present invention in its second aspect provides a cold rolled steel sheet having the following physical target values:

TS  $\geq$  45 Kg/mm<sup>2</sup>  
 TS x EI  $\geq$  1800 Kg/mm<sup>2</sup>.%  
 r-value (mean)  $\geq$  1.5  
 BH  $\geq$  3.5 Kg/mm<sup>2</sup>.

5 yield point elongation immediately after annealing, hot-dip galvannealing or skin-pass rolling or after 6-month aging after such treatment

< 0.5 %.

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As stated before, the present invention is aimed at eliminating impairment of workability which hitherto has been inevitably caused in strengthening a steel sheet having a dual-phase structure composed of an ordinary high-temperature transformed ferrite phase which includes a recrystallized ferrite having same form as the ordinary high-temperature transformed ferrite, and a low-temperature transformed ferrite phase which

15 has high dislocation density.

The steel sheet in accordance with the first aspect of the invention has been obtained as a result of discovery of the fact that addition of at least one strengthening elements selected from Ni, Mo and Cu is very effective in achieving the above-described aim.

20 The steel sheet in accordance with the second aspect has been obtained on the basis of discovery of the fact that addition of C and Nb is effective.

#### BRIEF DESCRIPTION OF THE DRAWINGS

25 Fig. 1 is a graph showing influence of Ni, Cu or Mo on the balance between tensile strength (TS) and elongation (EI) of a steel sheet after an annealing;

Fig. 2 is a graph showing influence of C on the TS-EI balance of a steel sheet after annealing;

Fig. 3 is a graph showing influence of Nb and Ti on the r-value of a steel sheet after annealing;

Fig. 4 is a microscopic photograph (x400) of a composite structure in a steel sheet (steel No. 8 in Table 3) produced in accordance with the method of the present invention; and

30 Fig. 5 is a microscopic photograph (x400) of a structure in a compared steel sheet (steel No. 13A in Table 3).

#### DETAILED DESCRIPTION OF THE INVENTION

35 A detailed description will now be given of the method of producing the steel sheet in accordance with the first aspect.

An experiment was conducted to examine the result of addition of the strengthening elements such as Ni, Mo and Cu.

40 Cold rolled steel sheets were produced under the following conditions using three types of continuously-cast slabs having different compositions as shown in Table 1, and the tensile strengths of the thus obtained steel sheets were measured.

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50

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Table 1

Steel No.	Class	Composition (wt %)												$\gamma$ Transforma- tion Start Temp. (°C)
		C	Si	Mn	Nb	B	$\lambda^{\circ}$	P	S	N	Ni	Mo	Cu	
A	Steel of Invention	0.0046	0.05	0.49	0.041	0.0020	0.047	0.048	0.005	0.0021	0.62	0.50	-	900
B	ditto	0.0048	0.05	0.50	0.042	0.0020	0.043	0.047	0.004	0.0023	-	-	0.21	900
C	Comp. Ex.	0.0045	0.04	0.52	0.040	0.0021	0.044	0.044	0.005	0.0022	-	-	-	910

Conditions:

Hot rolling condition:

Slab heating temperature (SRT): 1200 °C

Table 3

Steel No.	Content	Process	Overall	Hot Rolling Condition			Cold Rolling Reduction Ratio (%)	$\gamma$ Transformation Temp.		Annealing Condition		Alloying Hot-Dip Zinc Plating	Skin-pass Rolling (%)
				SPR (°C)	1DT (°C)	CT (°C)		Start Temp. (°C)	Finish Temp. (Ac3)(°C)	Annealing Temp. (°C)	Cooling Rate (°C/sec.)		
1A	Steel of Invention	Steel of Invention	Steel of Invention	1200	890	600	77	930	970	950	25	No	No
1B	ditto	ditto	ditto	1200	890	600	77	930	970	950	20	No	1.0
1C	ditto	ditto	ditto	1200	890	600	77	930	970	950	20	Yes (550°C)	No
1D	ditto	Comp. Ex.	Comp. Ex.	1200	890	600	77	930	970	850	20	No	No
1E	ditto	ditto	ditto	1200	890	600	77	930	970	950	13	No	No
1F	ditto	ditto	ditto	1200	890	600	56	930	970	950	20	No	No
2	ditto	Steel of Invention	Steel of Invention	1200	880	700	78	900	970	920	20	No	No
3A	ditto	ditto	ditto	1150	880	650	78	870	940	900	30	No	No
3B	ditto	ditto	ditto	1150	880	650	78	870	940	900	30	Yes (550°C)	0.5
4	ditto	ditto	ditto	1250	890	500	70	870	960	880	15	No	No
5A	ditto	ditto	ditto	1200	860	550	78	830	890	850	50	No	No
5B	ditto	Comp. Ex.	Comp. Ex.	1200	860	550	78	830	890	850	50	No	No
6	ditto	Steel of Invention	Steel of Invention	1100	900	700	80	910	990	930	7	No	No
7	ditto	ditto	ditto	1200	890	650	73	930	980	940	80	No	No
8	ditto	ditto	ditto	1200	890	600	73	890	930	920	30	No	No
9	ditto	ditto	ditto	1200	910	650	78	910	970	920	20	No	No
10	ditto	ditto	ditto	1150	900	550	78	910	940	920	25	No	No
11	ditto	ditto	ditto	1200	900	700	75	840	930	860	25	No	0.5
12	ditto	ditto	ditto	1150	920	600	60	900	950	920	5	No	No
13A	Comp. Ex.	ditto	Comp. Ex.	1100	890	650	78	900	950	920	25	No	No
13B	ditto	ditto	ditto	1100	890	650	78	900	950	920	25	Yes (550°C)	No
14	ditto	ditto	ditto	1200	890	600	77	830	890	850	30	No	No
15	ditto	ditto	ditto	1150	890	600	73	820	910	850	40	No	No
16	ditto	ditto	ditto	1200	900	700	77	900	950	920	40	No	No
17	ditto	ditto	ditto	1250	900	500	78	840	950	850	35	No	No
18	ditto	ditto	ditto	1150	920	600	70	930	980	950	15	No	No
19	ditto	ditto	ditto	1150	890	500	78	870	920	890	15	No	No

Note: Mark  $\gamma$  shows contents out of ranges of the invention.

Table 4

Steel No.	Class	YS (Kgf/mm <sup>2</sup> )	TS (Kgf/mm <sup>2</sup> )	E <sub>t</sub> (%)	TSME (Kgf/mm <sup>2</sup> )	r Value (Mean)	BH (Kgf/mm <sup>2</sup> )	Non-aging property at room temp.			2nd Phase Vol. Ratio (%)	Grain Size Ratio (2nd Phase/Matrix Phase)
								Immediately After Annealing	After Aging	VEF (%)		
1A	Steel of Invention	26.5	45.8	41.7	1910	2.2	4.0	0.0	0.0	0.0	30	1
1B	ditto	27.3	46.0	41.7	1918	2.2	4.0	0.0	0.0	0.0	30	1
1C	ditto	27.4	46.8	40.8	1909	2.1	3.9	0.0	0.0	0.0	30	1
1D	Comp. Ex.	20.4	33.2	57.8	1919	2.0	3.8	0.5	2.8	0	0	-
1E	ditto	25.7	43.5	42.0	1827	1.8	3.8	0.4	1.5	<1	0	0.1
1F	ditto	26.9	45.0	38.9	1751	1.5	3.9	0.0	0.2	0	30	3.5
2	Steel of Invention	35.7	60.2	31.7	1908	2.1	5.3	0.0	0.0	0.0	20	1.5
3A	ditto	29.7	51.5	37.0	1906	2.0	4.4	0.0	0.0	0.0	40	2
3B	ditto	30.5	52.0	36.7	1908	2.0	4.4	0.0	0.0	0.0	40	2
4	ditto	31.0	52.9	36.0	1904	2.1	4.0	0.0	0.0	0.0	5	3
5A	ditto	30.1	50.4	37.7	1900	2.0	4.6	0.0	0.0	0.0	10	2.5
5B	Comp. Ex.	35.1	55.2	22.3	1231	1.4	4.5	0.0	0.0	0.0	90	7
6	Steel of Invention	33.0	55.7	34.2	1905	2.0	4.0	0.0	0.0	0.0	20	3
7	ditto	24.4	40.3	47.6	1918	2.2	3.8	0.0	0.0	0.0	70	1
8	ditto	28.9	50.2	38.9	1953	2.3	0.2	0.0	0.0	0.0	10	0.5
9	ditto	26.6	47.8	40.8	1950	2.2	4.7	0.0	0.0	0.0	20	1
10	ditto	25.4	45.2	43.5	1966	2.3	3.5	0.0	0.0	0.0	20	1.5
11	ditto	36.0	60.8	31.4	1909	2.0	4.8	0.0	0.0	0.0	50	1
12	ditto	29.5	51.3	38.4	1970	2.2	4.2	0.0	0.0	0.0	30	1.5
13A	Comp. Ex.	35.4	46.5	25.4	1181	1.4	3.2	0.1	0.6	0.6	20	10
13B	ditto	37.2	47.2	19.8	935	1.2	2.8	0.7	1.2	1.2	20	10
14	ditto	45.7	57.9	15.2	880	1.3	3.8	0.0	0.0	0.0	30	3.5
15	ditto	43.1	55.4	18.8	1042	1.3	4.0	0.0	0.0	0.5	30	4
16	ditto	40.0	52.6	25.4	1336	1.2	3.8	0.0	0.0	0.0	20	5
17	ditto	37.4	48.7	22.4	1091	1.4	5.1	0.0	0.0	0.0	30	4
18	ditto	33.4	44.7	42.6	1904	1.1	2.2	0.8	2.9	0	0	-
19	ditto	33.9	45.1	42.9	1935	1.1	2.4	1.0	3.0	0	0	-

The measuring methods and conditions were as follows.

Tensile characteristic:

The tensile characteristics were measured by using a test piece No. 5 as specified by JIS (Japanese Industrial Standards) Z 2201.

r-value (mean):

The mean r-value was determined by measuring the Lankford value (r-value) by three-point method under 15 % tension in three directions: namely, L direction (direction of rolling), D direction (direction which is 45° to the rolling direction) and C direction (direction 90° to the rolling direction), and calculating the mean value in accordance with the following formula:

$$\text{mean r-value} = (r_L + 2 r_D + r_C)/4$$



Bake hardenability:

The level of stress ( $\sigma_2$ ) under 2 % tensile strain was measured. Measure also was the level of yield stress ( $\sigma_y$ ) after 2-hour aging at 170 °C following release of 2 % tensile pre-loading. The work hardenability (BH) was then determined in accordance with the following formula:

$$BH = (\sigma_y) - (\sigma_2)$$

Non-aging property at room temperature:

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Yield elongation (YEL) was measured by conducting a tensile test (tensile speed 10 mm/min) immediately after the annealing. The yield elongation also was measured after a 10-hour aging treatment at 100 °C corresponding to 6-month aging at 30 °C. The non-aging property at room temperature was then evaluated by using these two measured values of yield elongation.

15

Fig. 4 shows microscopic photograph (x400) of the dual-phase structure in a steel sheet (steel No. 8) produced in accordance with the present invention. And Fig. 5 shows microscopic photograph (x400) of a structure in a compared example of steel sheet (steel No. 13A).

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From Table 4, it will be understood that all the steel sheets which satisfy the requirements of the first aspect of the present invention exhibit tensile strength (TS) of 40 Kgf/mm<sup>2</sup> or greater, as well high degrees of non-aging property at room temperature and workability. In addition, all the steel sheets of the first aspect of the invention, excepting the steel No. 8 in which all part of solid-solution C is fixed by Ti, had bake hardenability of not less than 3.5 Kgf/mm<sup>2</sup>. Furthermore, no degradation of material was observed in the steel sheets which had undergone hot-dip zinc plating by CGL or refining rolling.

25

On the other hand, the following facts were noted on the steel sheets of comparative examples.

Steel No. 1D

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Inferior non-aging property at room temperature was observed due to the facts that the annealing temperature was lower than the  $\gamma$  transformation temperature and that the structure consisted of  $\alpha$  phase alone.

Steel No. 1E

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Inferior non-aging property at room temperature was observed due to the facts that the rate of cooling after the annealing was too small and that the structure was constituted substantially by  $\alpha$  phase alone.

Steel No. 1F

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Inferior workability was observed due to too large grain size of the second phase as compared with that of the matrix phase, as a result of too small rolling reduction in the cold rolling.

Steel No. 5B

45

Workability was unsatisfactory due to the fact that the annealing was executed at a temperature higher than the temperature region where  $\alpha$  and  $\gamma$  phases coexist.

Steel Nos. 13A and 13B

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These steels were free of Cu, Ni and Mo. Consequently, the grain sizes of the second phase in each of these steels were excessively large as compared with that of the matrix phase, which deteriorated workability and adversely affected the non-aging property at room temperature. The undesirable effect on the aging resistance is serious particularly in the steels which have undergone the hot-dip galvannealing.

Steel Nos. 14 and 15

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The ratio between the grain size of the second phase and that of the matrix phase does not fall within the range specified by the invention, due to excessively large content of Ni, Mo or Cu. Consequently, good workability could not be obtained.

Steel No. 16

The ratio between the grain size of the second phase and that of the matrix phase does not fall within the range specified by the invention due to excessively large content of Mn. Consequently, good workability  
5 could not be obtained.

Steel No. 17

Workability was adversely affected by too large Nb content.  
10

Steel Nos. 18 and 19

Low-temperature transformed ferrite phase was not formed due to lack of Nb or B. Consequently, workability and non-aging property at room temperature were unsatisfactory.

15 Thus, all the comparative example were inferior to the steel sheets in accordance with the first aspect of the present invention.

A detailed description will now be given of a method of producing the steel sheet in accordance with the second aspect of the present invention.

As explained before, the steel sheet in accordance with the second aspect features a tensile strength of  
20  $TS \geq 45 \text{ Kg/mm}^2$  in contrast to the steel of the first aspect having tensile strength of  $TS \geq 40 \text{ Kg/mm}^2$ , and possesses bake hardenability in addition to the advantageous features of the steel of the first aspect. The present inventors have found that such high tensile strength and superior bake hardenability are obtainable by addition of controlled amount of C and Nb.

An experiment was conducted to examine the result of addition of C.

25 Cold rolled steel sheets D and E were produced under the following conditions using two types of continuously-cast slabs having different C contents as shown in Table 5, and the tensile strengths of the thus obtained steel sheets were measured.

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50

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Table 5

Steel No.	Class	Composition (wt %)										Transformation Start Temp. (°C)
		C	Si	Mn	Nb	B	Al	P	S	N	Nb/C	
D	Steel of Invention	0.011	0.05	0.49	0.085	0.0015	0.062	0.045	0.007	0.0024	7.7	890
E	Comp. Ex.	0.0036	0.05	0.47	0.032	0.0014	0.062	0.048	0.008	0.0022	8.9	920

Conditions:

Hot rolling condition:

Slab heating temperature (SRT): 1200 °C  
 Hot rolling finish temperature (FDT): 900 °C

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Coiling temperature (CT): 650 °C

Final sheet thickness: 3.2 mm

Cold rolling condition:

Rolling reduction: 78 %

Final sheet thickness: 0.7 mm

Continuous annealing condition:

Heating temperature:

Steel D 880 to 950 °C (5 °C gradation)

Steel E 910 to 950 °C (5 °C gradation)

Cooling rate: 30 °C/sec

The results of measurement are shown in Fig. 2 which illustrates influence of C on the balance between tensile strength (TS) and elongation (EI).

As will be clear from Fig. 2, the steel E which has a small C content of 0.0036 wt% exhibits a drastic reduction of EI when TS is 45 Kgf/mm<sup>2</sup> or therearound and cannot provide any TS value higher than 45 Kgf/mm<sup>2</sup>. In contrast, steel D containing 0.011 wt% of C does not exhibit drastic reduction in EI when TS is increased, while exhibiting tensile strength of 45 Kgf/mm<sup>2</sup> or greater, thus proving high-stability against strengthening treatment and two-phase-range annealing.

Hitherto, it has been considered that increase in the C content inevitably causes a large reduction in the r-value. Reduction of the r-value in accordance with increase in the C content was generally observed also in experiments which were conducted on steel sheets having dual-phase structure composed of high-temperature transformed ferrite phase and low-temperature transformed phase.

The present inventors, however, found that there exists a certain measure for avoiding reduction of the r-value in the steel sheets having above-mentioned dual-phase structure, provided that the C content is not more than 0.025 wt%, through an experiment.

The result of the experiment will be described hereinafter. Steel slabs of group F with varying Nb content and steel slabs of group G with varying Ti content were produced to have compositions as shown in Table 6, and these steel slabs were tested for measurement of r-values.

Table 6

Steel No.	Composition (wt %)										Transforma- tion Start Temp. (°C)
	C	Si	Mn	B	Al	P	S	N	Others	Nb/C or Ti*/C	
Group F	0.012	0.1	0.3	0.002	0.06	0.03	0.01	0.003	Nb: 0-0.25	0-20.8	890
Group G	0.012	0.1	0.3	0.002	0.06	0.03	0.01	0.003	Ti: 0-0.145	0-10.0	890
										(Weight Ratio)	(Atom Ratio)

Note: Ti\* = [Ti] - 48/32 [S] - 48/14 [N]

55 Slab producing conditions:

Hot rolling condition:

Slab heating temperature (SRT): 1250 °C

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Hot rolling finish temperature (FDT): 900 ° C

Coiling temperature (CT): 620 ° C

Final sheet thickness: 3.5 mm

Cold rolling condition:

Rolling reduction: 80 %

Final sheet thickness: 0.7 mm

Continuous annealing condition:

Heating temperature: 910 ° C

Cooling rate: 95 ° C/sec

Refining rolling

Elongation: 0.8 %

The results of the measurement are shown in Fig. 3. Thus, Fig. 3 shows influences of Nb and Ti on the r-value.

Referring to Fig. 3,  $Ti^*$  indicates effective Ti content which is calculated in accordance with the following formula:

$$Ti^* = [Ti] - 48/32 [S] - 48/14 [N]$$

From Fig. 3, it will be seen that high r-values are obtained in the steel sheets of the group F containing Nb, i.e., in the steel sheets in which C is fixed by Nb.

This advantageous effect is considered as being attributable to the following function performed by Nb.

The r-value, considered in connection with the crystal grain growth, increases where greater crystal grain growth speed is obtained within the temperature range where  $\alpha$  phase exists alone in the course of annealing, as is the case of ordinary soft steels. From this point of view, it is preferred to add an element which fixes C. On the other hand, in the temperature range in which  $\alpha$  and  $\gamma$  phases coexist, it is necessary to suppress coarsening of the  $\gamma$  phase in order to prevent reduction in the r-value. To this end, it is preferred to allow C to exist in the form of solid solution. Considering that decomposition of NbC occurs at temperatures just around the  $\gamma$  transformation temperature, it is understood that C is dissolved so as to realize the above-mentioned optimum condition at temperatures above the  $\gamma$  transformation temperature. Both the steels shown in Tables 5 and 6 showed a second-phase content (content of low-temperature transformed ferrite phase) of 1 to 70 % when the annealing was conducted at temperatures higher than the  $\gamma$  transformation temperature, thus exhibiting appreciably high non-aging property at room temperature, as well as bake hardenability. The second phase appears in one of the aforementioned three forms or a combination of two or more of these three forms, depending on the contents of C, Ni, Mo and Cu. However, no substantial correlation was observed between the form and absolute grain size of the second phase and the workability.

General steels which are comparatively rich in strengthening elements tend to allow growth of the second phase grains to sizes greater than the grain size of the matrix phase (high-temperature transformed ferrite phase), more specifically to sizes which are more than three times as large that of the matrix phase grains. This should be contrasted to the steel sheets having compositions falling within the ranges specified by the invention which exhibit superior workability and which have mean grain size of second phase less than three times that of the matrix grain size. This fact gives a support to the aforementioned discovery that the promotion of growth of  $\alpha$  grains and suppression of growth of  $\gamma$  grains produce desirable effects on the material.

A description will now be given of the reasons of limitation of contents of the constituents in the steel sheet according to the first aspect of the invention.

The contents of Si, Mn, B, Al, P and N are the same as those of the steel in accordance with the first aspect of the invention.

C: 0.008 to 0.025 wt%

When C content is 0.008 wt% or less, it is impossible to obtain high strength without impairing workability. Conversely, C content exceeding 0.025 wt% makes it impossible to suppress reduction in the r-value and causes martensitization of the second phase, resulting in problems such as softening and strain aging at room temperature when the steel sheet is plated by hot-dip galvannealing. The C content, therefore, is determined to be more than 0.008 wt% but not more than 0.025 wt%.

Si: 1.0 wt% or less

Si content exceeding 1.0 wt% raises the transformation point to require annealing at elevated temperature. In addition, plating adhesion is impaired when the steel sheet having such large Si content is subjected to hot-dip zinc plating. The Si content is therefore determined to be 1.0 wt% or less. On the other hand, inclusion of Si by 0.05 wt% or more is effective in increasing strength, while improving the balance between strength and elongation more or less. This is considered to be attributable to promotion of enrichment of the second phase with C effected by the presence of Si.

Mn: 0.1 to 2.0 wt%

Harmful sulfides (FeS) tend to be formed when Mn content is less than 0.1 wt%. However, inclusion of Mn in excess of 2.0 wt% seriously affects the strength-elongation balance. The content of Mn, therefore, should be determined to be not less than 0.1 wt% but not more than 2.0 wt%. Preferably, the Mn content is determined to be 1.0 wt% or less.

Nb: 0.2 wt% or less, five times or more greater than  $C^*$

Nb is an element which, in cooperation with B, promotes formation of low-temperature transformed ferrite. Nb, when its content (wt %) is equal to or greater than the value which is five times greater than that of solid solution C, it is possible to form carbide to fix C thereby preventing degradation of r-value caused by solid solution C in the beginning period of annealing. In the latter period of the annealing, the carbide is decomposed to impart bake hardenability. Thus, Nb plays the most important role in the second steel sheet in accordance with the present invention. Nb content exceeding 0.2 wt% adversely affects the workability. Consequently, the Nb content is determined to be not less than 0.001 wt% but not more than 0.2 wt%. The content of Nb, therefore, should be determined to be not more than 0.2 wt% but five times or more greater than  $C^*$  which is expressed as follows:

For Ti content given by  $Ti = 48/32[S] + 48/14[N]$  or smaller:

$C^* = [C]$

For greater Ti content:

$C^* = [C] + 12/32[S] + 12/48 [N] - 12/48 [Ti]$

B: 0.0003 to 0.01 wt%

B is an element which, in cooperation with Nb, promotes formation of low-temperature transformed ferrite. The effect of addition of B, however, is not appreciable when the B content is below 0.0003 wt%. Conversely, B content exceeding 0.01 wt% adversely affects the workability. Consequently, the B content is determined to be not less than 0.0003 wt% but not more than 0.01 wt%.

Al: 0.005 to 0.10 wt%

Al is an element which is essential for enabling deoxidation during refining. To obtain an appreciable effect, the Al content should be 0.005 wt% or more. Any Al content exceeding 0.10 wt%, however, increases inclusions with the result that the material is degraded. The Al content, therefore, should be determined to be not less than 0.005 wt% but not more than 0.10 wt%.

P: 0.1 wt% or less

Presence of P in excess of 0.1 wt%, however, not only enhances surface defect due to segregation but also impairs adhesion of plating layer in hot-dip zinc plating. In addition, presence of P in such an amount undesirably suppresses the strengthening effect produced by the second phase. The P content, therefore, should be determined to be not more than 0.1 wt%. Preferably, the P content is determined to be 0.05 wt% or less.

N: 0.007 wt% or less

N deteriorates both workability and aging resistance at room temperature when its content exceeds 0.007 wt%. In addition, presence of N in such an amount wastefully consumes B due to formation of BN. The N content, therefore, should be determined to be 0.007 wt% or less. Ti: 0.005 wt% to a value given by  $48/12 [\text{Cwt}\%] + 48/32 [\text{Swt}\%] + 48/14 [\text{Nwt}\%]$

5 Ti is an element which fixes both S and N so as to suppress undesirable effect on the yield of B and the material. Any excess Ti, i.e., Ti content (wt%) beyond the value expressed by  $48/32 [\text{Swt}\%] + 48/14 [\text{Nwt}\%]$ , serves to fix solid solution C more efficiently than Nb does. Inclusion of Ti by 0.005 wt% or more, therefore, is expected to improve workability. A too large Ti content, however, tends to cause surface defect. In addition, since Ti carbide is difficult to decompose, desired bake hardenability cannot be obtained  
10 when whole solid solution C is fixed by Ti and, in addition, high r-value which is considered to be a result of fixing of C by Nb is impaired. Consequently, the Ti content is determined to be not less than 0.005 wt% and not more than a value which is given by  $48/12 [\text{Cwt}\%] + 48/32 [\text{Swt}\%] + 48/14 [\text{Nwt}\%]$ .

S: 0.050 wt% or less

15 A tends to cause hot-work embrittlement when its content exceeds 0.050 wt%, so that S content is limited so as not to exceed 0.050 wt%. Even when S is made to precipitate by S, workability is impaired due to increase in the inclusions when S content exceeds 0.050 wt%.

20 Conditions for producing the steel sheet in accordance with the second aspect of the invention, such as conditions for forming the slabs, hot-rolling conditions, coiling temperature, cold rolling conditions, annealing conditions, rate of cooling after annealing and refining rolling conditions are the same as those employed in the production of the steel sheets in accordance with the first aspect of the present invention.

## Example 2

25 Slabs of 9 types steels having compositions falling within the range specified by the invention and 6 types of comparative example steels having compositions falling out of the range of the invention were prepared by continuous casting. The compositions of these steels are shown in Table 7. These steel slabs were hot-rolled (final thickness 1.6 to 3.5 mm), cold rolled (final thickness 0.7 mm) and then annealed,  
30 under conditions as shown in Table 8. Some of the steel slabs were further subjected to hot-dip galvannealing or skin-pass rolling the conditions of which also are shown in Table 3.

The hot-dip galvannealing shown in Table 8 was conducted in a continuous galvannealing line (CGL) which sequentially performs annealing, hot-dip zinc plating and alloying treatment (550°C, 20 sec). No inferior adhesion of plating layer was found in each case.

35 The steel sheet products thus obtained were subjected to measurement of tensile characteristics, r-value, bake hardenability, and non-aging property at room temperature, as well as to an examination of the structure. The results are shown in Table 9.



Table 7

Steel No.	Class	Composition (wt %)											Nb/C*	Ti*
		C	Si	Mn	Nb	B	Al	P	S	N	Ti			
20	Steel of Invention	0.011	0.31	0.24	0.087	0.0023	0.062	0.039	0.007	0.0024	-	7.9		
21	ditto	0.0085	0.01	0.37	0.066	0.0027	0.051	0.027	0.008	0.0033	-	7.8		
22	ditto	0.021	0.23	0.55	0.160	0.0041	0.080	0.040	0.007	0.0020	-	7.6		
23	ditto	0.012	0.18	0.97	0.100	0.0007	0.021	0.019	0.009	0.0040	0.016	8.3	0.062	
24	ditto	0.015	0.33	0.84	0.048	0.0018	0.034	0.042	0.010	0.0034	0.062	7.8	0.086	
25	ditto	0.010	0.25	0.64	0.075	0.0019	0.045	0.087	0.010	0.0031	-	7.5		
26	ditto	0.0095	0.72	1.87	0.056	0.0032	0.051	0.011	0.005	0.0021	-	5.9		
27	ditto	0.013	0.46	0.95	0.150	0.0081	0.041	0.043	0.006	0.0030	-	11.5		
28	ditto	0.025	0.20	0.61	0.20	0.0044	0.058	0.031	0.005	0.0027	-	8		
29	Comp. Ex.	☆0.0034	0.03	1.24	0.046	0.0028	0.048	0.034	0.007	0.0024	-	13.5		
30	ditto	☆0.047	0.45	1.02	0.140	0.0027	0.039	0.031	0.008	0.0024	-	☆3.0		
31	ditto	☆0.038	0.32	0.13	☆0.340	0.0046	0.055	0.035	0.006	0.0023	-	8.9		
32	ditto	0.011	0.60	0.86	☆0.460	0.0033	0.056	0.063	0.008	0.0028	-	41.8		
33	ditto	0.012	0.29	1.35	0.039	0.0026	0.035	0.042	0.007	0.0031	-	☆3.3		
34	ditto	0.011	0.06	0.98	0.042	0.0031	0.045	0.037	0.007	0.0022	☆0.089	-	0.075	

Note: 1. Mark ☆ shows contents out of ranges of the invention.

2. When Ti is not added, and when  $Ti \leq 40/32$  and  $[S] + 48/14 [N] : C^* = C$

When  $Ti > 48/32 [S] + 48/14 [N]$ ,  $C^* = [C] + 12/32 [S] + 12/14 [N] - 12/48 [Ti]$

3.  $Ti^* = 48/12 [C] + 48/32 [S] + 40/14 [N]$

Table 8

Steel No.	Content	Process	Overall	Hot Rolling Condition			Cold Rolling Reduction Ratio (%)	r Transformation Temp.		Annealing Condition		Alloying Hot-Dip Zinc Plating	Skin-pass Rolling (%)
				SRT (°C)	PDR (°C)	CT (°C)		Start Temp. (°C)	Finish Temp. (Ac3)(°C)	Annealing Temp. (°C)	Cooling Rate (°C/sec.)		
20A	Steel of Invention	Steel of Invention	Steel of Invention	1200	880	650	75	910	990	930	25	No	No
20B	ditto	ditto	ditto	1200	880	650	75	910	990	930	25	No	1.0
20C	ditto	ditto	ditto	1200	880	650	75	910	990	930	25	Yes (550°C)	No
20D	ditto	Comp. Ex.	Comp. Ex.	1200	880	650	75	910	990	☆850	25	No	No
20E	ditto	ditto	ditto	1200	880	650	75	910	990	930	☆3	No	No
20F	ditto	ditto	ditto	1200	880	650	☆56	910	990	930	25	No	No
21	ditto	Steel of Invention	Steel of Invention	1150	900	550	80	900	970	920	50	No	No
22A	ditto	ditto	ditto	1100	860	700	75	850	960	870	35	No	No
22D	ditto	ditto	ditto	1100	860	700	75	850	960	870	35	Yes (550°C)	0.5
23	ditto	ditto	ditto	1250	890	650	77	850	930	880	10	No	No
24	ditto	ditto	ditto	1200	890	650	78	860	950	880	20	No	No
25	ditto	ditto	ditto	1200	890	650	75	910	1000	920	40	No	No
26A	ditto	ditto	ditto	1200	890	650	72	830	900	860	80	No	No
26B	ditto	Comp. Ex.	Comp. Ex.	1200	890	650	72	830	900	☆940	80	No	No
27	ditto	Steel of Invention	Steel of Invention	1200	890	680	75	870	960	890	30	No	No
28	ditto	ditto	ditto	1150	900	720	60	850	940	870	5	No	0.5
29	Comp. Ex.	ditto	Comp. Ex.	1200	910	650	75	870	930	910	30	No	No
30A	ditto	ditto	ditto	1100	890	650	75	760	890	820	25	No	No
30B	ditto	ditto	ditto	1100	890	650	75	760	890	820	25	Yes (550°C)	No
31	ditto	ditto	ditto	1200	890	650	75	800	960	850	60	No	No
32	ditto	ditto	ditto	1200	890	500	75	890	980	920	30	No	No
33	ditto	ditto	ditto	1150	890	500	75	840	930	880	15	No	No
34	ditto	ditto	ditto	1150	890	500	75	860	940	890	25	No	No

Note: Mark ☆ shows contents out of ranges of the invention.

Table 9

Steel No.	Class	YS (Kgf/mm <sup>2</sup> )	TS (Kgf/mm <sup>2</sup> )	E/ (%)	TSNEf (Kgf/mm <sup>2</sup> ·%)	r Value (Mean)	BH (Kgf/mm <sup>2</sup> )	Non-aging property at room temp. Ytf (%)		2nd Phase Vol. Ratio (%)	Grain Size Ratio (2nd Phase/Matrix Phase)
								Immediately After Annealing	After Aging		
20A	Steel of Invention	30.5	52.1	35.6	1855	1.8	4.2	0.0	0.0	30	1.5
20B	ditto	30.7	52.2	35.5	1853	1.8	4.2	0.0	0.0	30	1.5
20C	ditto	30.7	52.3	35.5	1857	1.8	4.1	0.0	0.0	30	1.5
20D	Comp. Ex.	29.0	42.0	42.1	1768	1.3	3.6	0.8	2.6	0	-
20E	ditto	32.4	48.7	35.8	1743	1.5	3.7	0.5	1.2	< 1	0.1
20F	ditto	30.7	53.2	33.8	1798	1.0	4.0	0.0	0.0	30	4
21	Steel of Invention	27.6	46.7	38.6	1803	1.9	4.0	0.0	0.0	20	2
22A	ditto	33.3	55.8	32.7	1825	1.7	5.5	0.0	0.0	20	1
22B	ditto	33.5	56.0	32.6	1826	1.7	5.3	0.0	0.0	20	1
23	ditto	31.0	55.1	34.5	1901	1.7	4.0	0.0	0.0	30	1.5
24	ditto	31.8	55.4	35.3	1956	1.8	3.5	0.0	0.0	20	1.5
25	ditto	28.9	50.2	37.4	1877	1.9	3.7	0.0	0.0	5	0.5
26A	ditto	37.0	62.0	30.4	1885	1.6	4.0	0.0	0.0	30	3
26B	Comp. Ex.	42.1	63.5	10.4	660	1.1	3.9	0.0	0.0	80	8
27	Steel of Invention	34.1	55.6	31.4	1857	1.7	4.3	0.0	0.0	30	6
28	ditto	37.6	63.0	30.1	1896	1.6	4.5	0.0	0.0	30	1.2
29	Comp. Ex.	30.5	47.8	25.6	1224	1.3	3.4	0.0	0.0	60	4
30A	ditto	39.4	55.2	31.5	1739	1.1	5.0	0.1	0.6	50	1
30B	ditto	45.1	50.9	24.5	1247	1.0	4.5	0.8	3.4	50	1
31	ditto	35.8	53.4	33.1	1768	1.1	4.9	0.0	0.5	40	4
32	ditto	34.4	48.7	30.4	1400	1.4	3.8	0.0	0.0	30	4
33	ditto	33.9	49.4	35.0	1729	1.1	4.0	0.0	0.5	30	5
34	ditto	33.9	50.4	34.1	1719	1.2	0.0	0.0	0.0	20	6

The measuring methods and conditions were as follows.

Tensile characteristic:

The tensile characteristics were measured by using a test piece No. 5 as specified by JIS (Japanese Industrial Standards) Z 2201.

r-value (mean):

The mean r-value was determined by measuring the Lankford value (r-value) by three-point method under 15 % tension in three directions: namely, L direction (direction of rolling), D direction (direction which

is 45° to the rolling direction) and C direction (direction 90° to the rolling direction), and calculating the mean value in accordance with the following formula:

$$\text{mean } r\text{-value} = (r_L + 2 r_D + r_C)/4$$

Bake hardenability:

The level of stress ( $\sigma_2$ ) under 2 % tensile strain was measured. Measure also was the level of yield stress ( $\sigma_y$ ) after 2-hour aging at 170 °C following release of 2 % tensile pre-loading. The work hardenability (BH) was then determined in accordance with the following formula:

$$BH = (\sigma_y) - (\sigma_2)$$

Non-aging property at room temperature:

Yield elongation (YEI) was measured by conducting a tensile test (tensile speed 10 mm/min) immediately after the annealing. The yield elongation also was measured after a 10-hour aging treatment at 100 °C corresponding to 6-month aging at 30 °C. The non-aging property at room temperature was then evaluated by using these two measured values of yield elongation.

From Table 9, it will be understood that all the steel sheets which satisfy the requirements of the second aspect of the present invention exhibit tensile strength (TS) of 40 Kgf/mm<sup>2</sup> or greater, as well high degrees of non-aging property at room temperature and workability. Furthermore, no degradation of material was observed in the steel sheets which have undergone hot-dip zinc plating by CGL or refining rolling.

On the other hand, the following facts were noted on the steel sheets of comparative examples.

Steel No. 20D

Inferior non-aging property at room temperature was observed due to the facts that the annealing temperature was lower than the  $\gamma$  transformation temperature and that the structure consisted of  $\alpha$  phase alone.

Steel No. 20E

Inferior non-aging property at room temperature was observed due to the facts that the rate of cooling after the annealing was too small and that the structure was constituted substantially by  $\alpha$  phase alone.

Steel No. 20F

Inferior workability was observed due to too large grain size of the second phase as compared with that of the matrix phase, as a result of too small rolling reduction in the cold rolling.

Steel No. 26B

Workability was unsatisfactory due to the fact that the annealing was executed at a temperature higher than the temperature region where  $\alpha$  and  $\gamma$  phases coexist.

Steel No. 29

Material quality was degraded due to too small C content and increase in the strength.

Steel Nos. 30A, 30B and 31

Material quality was degraded due to too high C content and martensitization of the second phase. In particular, r-value was low due to martensitization of the second phase.

Steel No. 32

Workability was adversely affected by large Ni content.

## Steel No. 33

Workability was not appreciable because the Nb content ( $Nb < 5C^*$ ) was insufficient for suppressing undesirable effect on the workability of solid solution C.

## Steel No. 34

Workability was not appreciable because the whole solid solution C was fixed by Ti, due to inclusion of Ti by the amount expressed by  $Ti > 48/12[C] + 48/32[S] + 48/14[N]$ .

Thus, all the comparative example were inferior to the steel sheets in accordance with the first aspect of the present invention.

A detailed description will now be given of a method of producing the steel sheet in accordance with the second aspect of the present invention.

As will be understood from the foregoing description, according to the present invention, it is possible to suppress degradation of workability which is caused in strengthening a steel sheet having a dual-phase structure composed of a high-temperature transformed ferrite phase and low-temperature transformed ferrite phase having high dislocation density. Thus, the present invention provides a high strength cold rolled steel sheet which has excellent non-aging property at room temperature and, as desired, high level of bake hardenability, as well as excellent drawability, and which is not degraded even when subjected to hot-dip galvannealing. The steel sheet of the present invention, therefore, can suitably be used as materials of various industrial products such as automotive panels.

## Claims

1. A high strength cold rolled steel sheet having excellent non-aging property at room temperature and excellent drawability, said steel sheet having a dual-phase structure composed of a high-temperature transformed ferrite phase and a low-temperature transformed ferrite phase having high dislocation density, said steel sheet having a composition which essentially contains: not less than 0.001 wt% but not more than 0.025 wt% of C; not more than 1.0 wt% of Si; not less than 0.1 wt% but not more than 2.0 wt% of Mn; not less than 0.001 wt% but not more than 0.2 wt% of Nb; not less than 0.0003 wt% but not more than 0.01 wt% of B; not less than 0.005 wt% but not more than 0.10 wt% of Al; not more than 0.1 wt% of P; not more than 0.007 wt% of N; at least one selected from a group consisting of not less than 0.05 wt% but not more than 3.0 wt% of Ni; not less than 0.01 wt% but not more than 2.0 wt% of Mo; and not less than 0.05 wt% but not more than 5.0 wt% of Cu; and the balance being substantially Fe with inevitable impurities.
2. A high strength cold rolled steel sheet according to Claim 1, wherein said composition further contains at least one selected from the group consisting of not less than 0.05 wt% but not more than 3.0 wt% of Cr and not less than 0.005 wt% but not more than 1.0 wt% of Ti.
3. A method of producing a high strength cold rolled steel sheet having excellent non-aging property at room temperature and excellent drawability, comprising the steps of:
  - preparing a hot-rolled steel sheet having a composition which essentially contains: not less than 0.001 wt% but not more than 0.025 wt% of C; not more than 1.0 wt% of Si; not less than 0.1 wt% but not more than 2.0 wt% of Mn; not less than 0.001 wt% but not more than 0.2 wt% of Nb; not less than 0.0003 wt% but not more than 0.01 wt% of B; not less than 0.005 wt% but not more than 0.10 wt% of Al; not more than 0.1 wt% of P; not more than 0.007 wt% of N; and at least one selected from a group consisting of not less than 0.05 wt% but not more than 3.0 wt% of Ni; not less than 0.01 wt% but not more than 2.0 wt% of Mo; and not less than 0.05 wt% but not more than 5.0 wt% of Cu;
  - cold rolling said steel sheet at a rolling reduction not smaller than 60 %;
  - annealing the cold rolled steel sheet at a temperature not lower than the  $\gamma$  transformation start temperature but below  $A_{c3}$  transformation temperature; and
  - cooling the annealed steel sheet at a rate not smaller than 5°C/sec but not greater than 100°C/sec.
4. A method according to Claim 3, wherein said composition further contains at least one selected from the group consisting of not less than 0.05 wt% but not more than 3.0 wt% of Cr and not less than 0.005 wt% but not more than 1.0 wt% of Ti.

5. A high strength cold rolled steel sheet having excellent non-aging property at room temperature and bake hardenability, as well as excellent drawability, said steel sheet exhibiting a tensile strength not smaller than 45 Kg/mm<sup>2</sup> and having a dual-phase structure composed of a high-temperature transformed ferrite phase and a low-temperature transformed ferrite phase having high dislocation density, said steel sheet having a composition which essentially contains: more than 0.008 wt% but not more than 0.025 wt% of C; not more than 1.0 wt% of Si; not less than 0.1 wt% but not more than 2.0 wt% of Mn; not more than 0.2 wt% but not less than five times the content of C of Nb; not less than 0.0003 wt% but not more than 0.01 wt% of B; not less than 0.005 wt% but not more than 0.10 wt% of Al; not more than 0.1 wt% of P; not more than 0.007 wt% of N; and the balance being substantially Fe with inevitable impurities.

6. A high strength cold rolled steel sheet having excellent non-aging property at room temperature and bake hardenability, as well as excellent drawability, said steel sheet exhibiting a tensile strength not smaller than 45 Kg/mm<sup>2</sup> and having a dual-phase structure composed of a high-temperature transformed ferrite phase and a low-temperature transformed ferrite phase having high dislocation density, said steel sheet having a composition which essentially contains: more than 0.008 wt% but not more than 0.025 wt% of C; not more than 1.0 wt% of Si; not less than 0.1 wt% but not more than 2.0 wt% of Mn; not less than 0.005 wt% but not more than a value given by the following formula (1) of Ti; not more than 0.2 wt% but not less than five times the content of C of Nb; not less than 0.0003 wt% but not more than 0.01 wt% of B; not less than 0.005 wt% but not more than 0.10 wt% of Al; not more than 0.1 wt% of P; not more than 0.050 wt% of S; not more than 0.007 wt% of N; and the balance being substantially Fe with inevitable impurities:

$$\text{Ti wt}\% \leq 48/32 [\text{Swt}\%] + 48/14 [\text{Nwt}\%] \quad (1)$$

7. A high strength cold rolled steel sheet having excellent non-aging property at room temperature and bake hardenability, as well as excellent drawability, said steel sheet exhibiting a tensile strength not smaller than 45 Kg/mm<sup>2</sup> and having a dual-phase structure composed of a high-temperature transformed ferrite phase and a low-temperature transformed ferrite phase having high dislocation density, said steel sheet having a composition which essentially contains: more than 0.008 wt% but not more than 0.025 wt% of C; not more than 1.0 wt% of Si; not less than 0.1 wt% but not more than 2.0 wt% of Mn; Ti of an amount meeting the condition of the following formula (2); not more than 0.2 wt% but not less than five times the content of C\* given by the following formula (3) of Nb; not less than 0.0003 wt% but not more than 0.01 wt% of B; not less than 0.005 wt% but not more than 0.10 wt% of Al; not more than 0.1 wt% of P; not more than 0.050 wt% of S; not more than 0.007 wt% of N; and the balance being substantially Fe with inevitable impurities:

$$48/12 [\text{Cwt}\%] + 48/32 [\text{Swt}\%] + 48/14 [\text{Nwt}\%] - \text{Tiwt}\% > 48/32 [\text{Swt}\%] + 48/14 [\text{Nwt}\%] \quad (2)$$

$$\text{C}^* \text{ wt}\% = [\text{Cwt}\%] + 12/32 [\text{Swt}\%] + 12/14 [\text{Nwt}\%] - 12/48 [\text{Tiwt}\%] \quad (3)$$

8. A method of producing a high strength cold rolled steel sheet having excellent non-aging property at room temperature and bake hardenability, as well as excellent drawability, said method comprising the steps of:

preparing a hot-rolled steel sheet having a composition which essentially contains: more than 0.008 wt% but not more than 0.025 wt% of C; not more than 1.0 wt% of Si; not less than 0.1 wt% but not more than 2.0 wt% of Mn; not more than 0.2 wt% but not less than five times the content of C of Nb; not less than 0.0003 wt% but not more than 0.01 wt% of B; not less than 0.005 wt% but not more than 0.10 wt% of Al; not more than 0.1 wt% of P; not more than 0.007 wt% of N;

cold rolling the hot-rolled steel sheet at a rolling reduction not smaller than 60 %;

annealing the cold rolled steel sheet at a temperature which is not lower than the  $\gamma$  transformation start temperature but below the  $A_{c3}$  transformation temperature; and

cooling the annealed steel sheet at a rate not smaller than 5 °C/sec but not greater than 100 °C/sec.

9. A method of producing a high strength cold rolled steel sheet having excellent non-aging property at room temperature and bake hardenability, as well as excellent drawability, said method comprising the steps of:

preparing a hot-rolled steel sheet having a composition which essentially contains: more than 0.008 wt% but not more than 0.025 wt% of C; not more than 1.0 wt% of Si; not less than 0.1 wt% but not more than 2.0 wt% of Mn; not less than 0.005 wt% but not more than a value given by the following formula (1) of Ti; not more than 0.2 wt% but not less than five times the content of C of Nb; not less than 0.0003 wt% but not more than 0.01 wt% of B; not less than 0.005 wt% but not more than 0.10 wt% of Al; not more than 0.1 wt% of P; not more than 0.050 wt% of S; not more than 0.007 wt% of N; cold rolling the hot-rolled steel sheet at a rolling reduction not smaller than 60 %; annealing the cold rolled steel sheet at a temperature which is not lower than the  $\gamma$  transformation start temperature but below the  $A_{c3}$  transformation temperature; and cooling the annealed steel sheet at a rate not smaller than 5° C/sec but not greater than 100° C/sec.

$$Ti \text{ wt}\% \leq 48/32 [\text{Swt}\%] + 48/14 [\text{Nwt}\%] \quad (1)$$

10. A high strength cold rolled steel sheet having excellent non-aging property at room temperature and bake hardenability, as well as excellent drawability, said method comprising the steps of:

preparing a hot-rolled steel sheet having a composition which essentially contains: more than 0.008 wt% but not more than 0.025 wt% of C; not more than 1.0 wt% of Si; not less than 0.1 wt% but not more than 2.0 wt% of Mn; Ti of an amount meeting the condition of the following formula (2); not more than 0.2 wt% but not less than five times the content of C\* given by the following formula (3) of Nb; not less than 0.0003 wt% but not more than 0.01 wt% of B; not less than 0.005 wt% but not more than 0.10 wt% of Al; not more than 0.1 wt% of P; not more than 0.050 wt% of S; not more than 0.007 wt% of N; cold rolling the hot-rolled steel sheet at a rolling reduction not smaller than 60 %; annealing the cold rolled steel sheet at a temperature which is not lower than the  $\gamma$  transformation start temperature but below the  $A_{c3}$  transformation temperature; and cooling the annealed steel sheet at a rate not smaller than 5° C/sec but not greater than 100° C/sec.

$$48/12 [\text{Cwt}\%] + 48/32 [\text{Swt}\%] + 48/14 [\text{Nwt}\%] > Ti \text{ wt}\% > 48/32 [\text{Swt}\%] + 48/14 [\text{Nwt}\%] \quad (2)$$

$$C^* \text{ wt}\% = [\text{Cwt}\%] + 12/32 [\text{Swt}\%] + 12/14 [\text{Nwt}\%] - 12/48 [Ti \text{ wt}\%] \quad (3)$$

FIG. 1

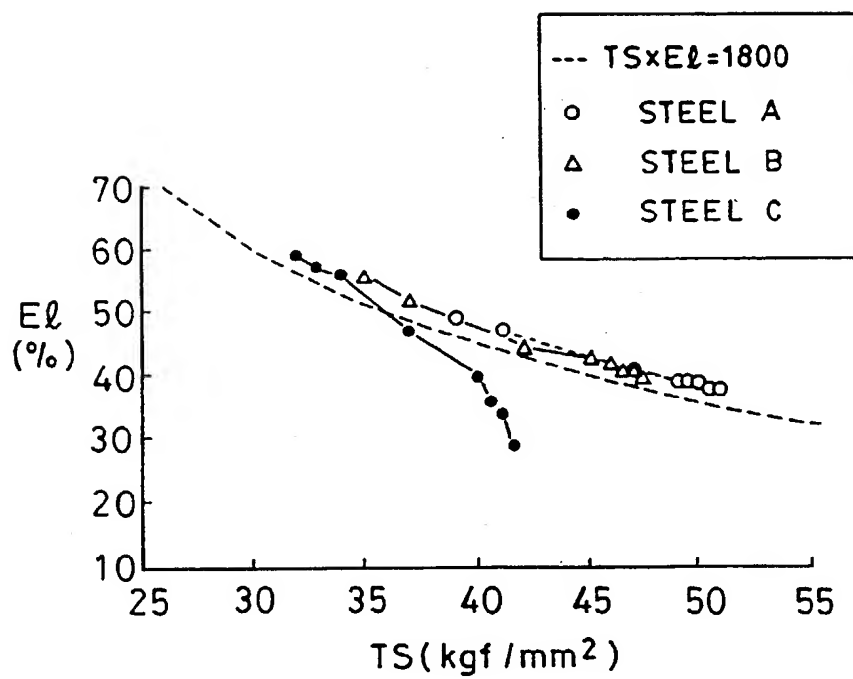




FIG. 2

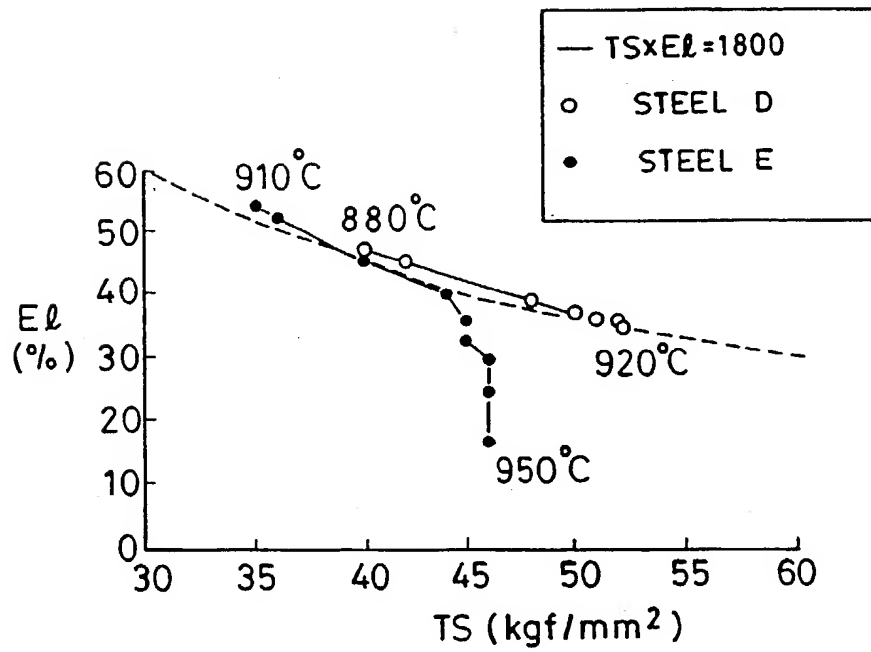


FIG. 3

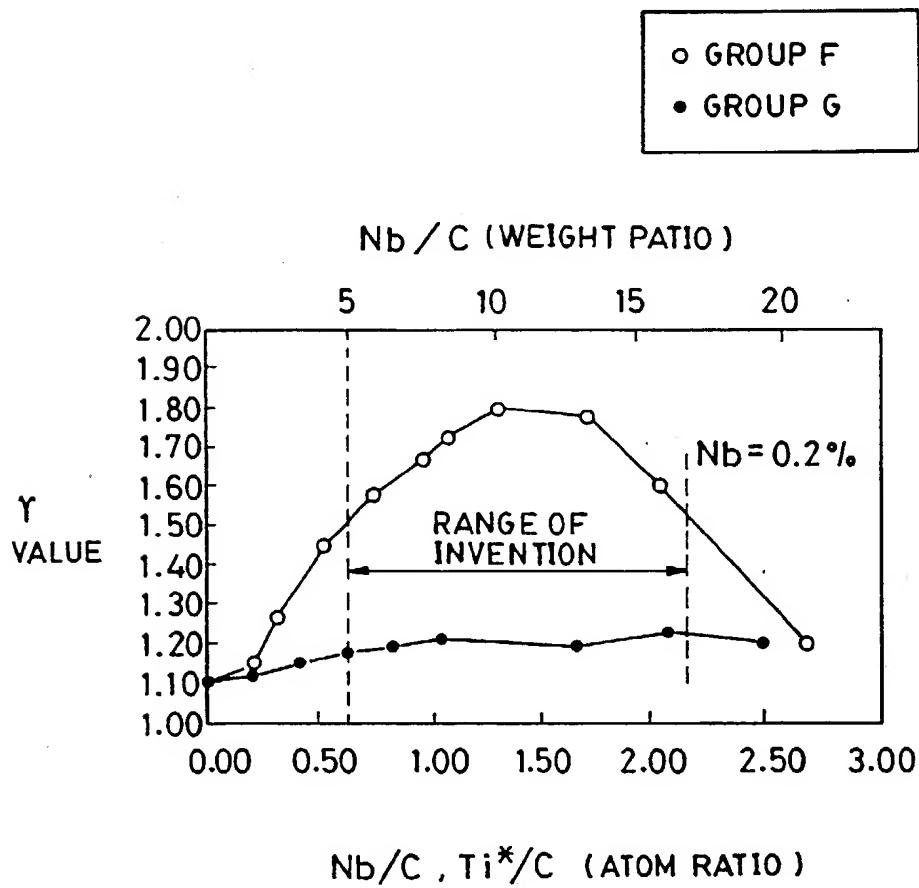
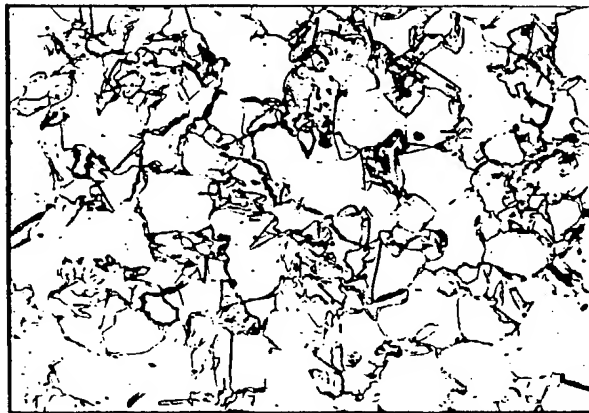
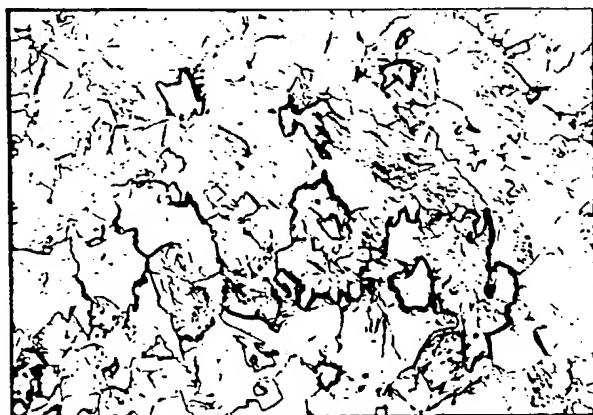


FIG. 4



( $\times 400$ )

FIG. 5



( $\times 400$ )

(13)



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(54) **High strength cold rolled steel sheet having excellent non-aging property at room temperature and suitable for drawing and method of producing the same.**

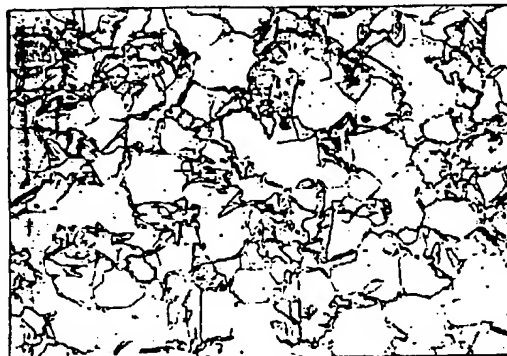
(57) The invention in its first aspect provides a high strength cold rolled steel sheet having excellent non-aging property at room temperature and excellent drawability, said steel sheet having a dual-phase structure composed of a high-temperature transformed ferrite phase and a low-temperature transformed ferrite phase having high dislocation density, said steel sheet having a composition which essentially contains: not less than 0.001 wt% but not more than 0.025 wt% of C, not more than 1.0 wt% of Si, not less than 0.1 wt% but not more than 2.0 wt% of Mn, not less than 0.001 wt% but not more than 0.2 wt% of Nb, not less than 0.0003 wt% but not more than 0.01 wt% of B, not less than 0.005 wt% but not more than 0.10 wt% of Al, not more than 0.1 wt% of P, not more than 0.007 wt% of N, at least one selected from a group consisting of not less than 0.05 wt% but not more than 3.0 wt% of Ni, not less

than 0.01 wt% but not more than 2.0 wt% of Mo and not less than 0.05 wt% but not more than 5.0 wt% of Cu, and the balance being substantially Fe with inevitable impurities. This steel sheet is produced by preparing a hot-rolled steel sheet having the above-specified composition, cold rolling the hot-rolled steel sheet at a rolling reduction not smaller than 60 %, annealing the cold rolled steel sheet at a temperature which is not lower than the  $\gamma$  transformation start temperatures but below the  $A_{c3}$  transformation temperature, and cooling the annealed steel sheet at a rate not smaller than 5 °C/sec but not greater than 100 °C/sec.

The invention in its second aspect provides a high strength cold rolled steel sheet having excellent non-aging property at room temperature and bake hardenability, as well as excellent drawability, said steel sheet exhibiting a tensile strength not smaller

than 45 Kgf/mm<sup>2</sup> and having a dual-phase structure composed of a high-temperature transformed ferrite phase and a low-temperature transformed ferrite phase having high dislocation density, said steel sheet having a composition which essentially contains: more than 0.008 wt% but not more than 0.025 wt% of C, not more than 1.0 wt% of Si, not less than 0.1 wt% but not more than 2.0 wt% of Mn, not more than 0.2 wt% but not less than five times the content of C of Nb, not less than 0.0003 wt% but not more than 0.01 wt% of B, not less than 0.005 wt% but not more than 0.10 wt% of Al, not more than 0.1 wt% of P, not more than 0.007 wt% of N, and the balance being substantially Fe with inevitable impurities. This steel sheet is produced by preparing a hot-rolled steel sheet having the above-specified composition, cold rolling the hot-rolled steel sheet at a rolling reduction not smaller than 60 %, annealing the cold rolled steel sheet at a temperature which is not lower than the  $\gamma$  transformation start temperature but below the  $A_{c3}$  transformation temperature, and cooling the annealed steel sheet at a rate not smaller than 5 °C/sec but not greater than 100 °C/sec.

FIG. 4



(×400)



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## EUROPEAN SEARCH REPORT

Application Number

EP 92 10 7173

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
P, X	EP-A-0 475 096 (KAWASAKI STEEL) * claims 1,2,3 * ---	1,5	C21D8/04 C22C38/12
A	EP-A-0 152 665 (KAWASAKI STEEL) * claims 1-4 * ---	1-10	
D	& JP-A-60 174 852 (KAWASAKI STEEL) ---		
A	EP-A-0 421 087 (KOBE STEEL) * claims 1,2 * ---	5	
A	EP-A-0 319 590 (NIPPON STEEL) * claim 8 * ---	1	
A	EP-A-0 108 268 (NIPPON STEEL) * claims 1-3 * -----	5	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			C21D C22C
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 22 JULY 1993	Examiner SUTOR W.
CATEGORY OF CITED DOCUMENTS			
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